suitable; their discrepancy is wiped out by small variation of air density or height of flight.

The practical airman will pay no heed to Mr. A. R. Low's elaborate explanation of the units employed in absolute measure (NATURE, January 5, p. 12). He has no use for poundal or slug units—fearful traps for the unwary and cause of great confusion of thought—and with the conceit to imagine they will pass current in the whole cosmos. But the rigour claimed for them is beginning to crack and show flaws under the merciless scrutiny of the new relativity.

Mr. Low is here coming to the rescue of the unhappy examinee, at the mercy of the whim of the examiner's text-book, and of the rigour demanded for the language employed there, ignored by the practical airman.

Divergence of language is never to disappear, as it seems, between science and engineering. The engineer refuses to budge when he finds he can arrive at a correct result in practice, and he ignores the rigour prescribed in the examiner's text-book as something to be thrown at the head of the examinee in his *conquête des diplômes*. G. GREENHILL.

Staple Inn, January 9.

Space and Æther.

THE relation of space and æther has been a subject of controversy. Three-dimensional absolute space has been regarded, before Einstein, as filled with a substantial æther. It is unnecessary to conceive the four-dimensional space-time of the relativists as so filled. If space-time is empty, is space also empty?

It seems to me that the crux of the difficulty is a wrong assumption that space-time is four-dimensional. Space-time is neither four-dimensional nor three-dimensional, but is two-dimensional. The orthodox analysis of the objective world down to the three fundamental entities of matter, space, and time has been incomplete. That which we call space also involves time. That which we call matter also involves both space and time. Thus what we call matter, space, and time should further be analysed as matter-space-time, space-time, and time where matter, space, and time with their new signification are fundamental entities. It is in this new sense that I shall use them hereafter.

Æther is the synthesis of space-times. It is matter-space-time. A synthesis is a petrified motion. We do not perceive the motion of æther because it is petrified. The motion in a space-time is independent of motion from space-time to space-time along the string that is æther. The so-called velocity of æther is not a change of space, but a change of matter.

Æther, being matter-space-time, partakes of the nature of all three. It has the density of matter, the rigidity of space, and the motion of time.

Æther is matter-space-time of no mind. The synthesis of matter-space-times of observing minds may be called hyper-æther—filling an absolute four-dimensional universe. Relatively to matter, æther is absolute. Relatively to mind, hyper-æther is absolute. The real is neither relative nor absolute, but is relatively absolute.

Einstein found that space-time was four-dimensional and that the universe was four-dimensional, and therefore argued that space-time was the universe. Therein lies his fallacy. His space-time is the two-dimensional section of a four-dimensional universe. There are two factors in evolution: persistence of identity and change of structure. As space-time is two-dimensional, its identity persists in the evolution from a three- to a four-dimensional universe. And as the world character changes, the internal structure of space-time changes. Einsteinian relativity is an anarchy. It marks a process of revolution, but does not attain a new position of stability.

Logic is not absolute, but is relative. The laws of logic of an absolute three-dimensional world are not the same as those of an absolute four-dimensional world. To study an absolute four-dimensional world we need a new logic, a new arithmetic, a new geometry, a new mechanics, and also a new science dealing not only with time as arithmetic does, not only with space as geometry does, not only with matter as mechanics does, but also with mind. On the recognition that time, space, matter, and mind contribute each a dimension to the universe I have been able to base an analytical geometry of the universe.

Space, in the sense of the arena of the three-dimensional universe, is matter-space-time, and may be regarded as filled with æther. The Euclido-Newtonian space-time and the Einsteinian space-time are non-material. But the latter is a stage of travail for the evolution of the former into a space-time with a new internal structure. The claim of the relativists to have demolished Euclid and Newton argues a want of the sense of historic perspective. Man does not progress by demolishing, but by building on, his past.

S. V. RAMAMURTY.

Trinity College, Cambridge, January 5.

Anisotropy of Molecules

DIRECT evidence that the molecules of gases are not spherically symmetrical and are anisotropic in their properties is furnished by the recent experiments of Lord Rayleigh, who has shown that the light scattered by molecules is, in general, not completely polarised when observed in a direction transverse to the pencil of light traversing the gas. The method used by Rayleigh, and by those who have repeated the experiments establishing this effect is a photographic one, the track of the primary beam of light as viewed through a suitably oriented prism of Iceland spar being recorded on a plate with long exposures. In view of the great interest of the phenomenon, it occurred to the present writer that it would be worth while to attempt direct *visual* observation and measurement of its magnitude. The chief obstacle is, of course, the extreme feebleness of the unpolarised part of the transversely scattered light. This has, however, been successfully overcome. By using the strongest possible illumination (sunlight), securing a perfectly black background, and very carefully screening the eye from extraneous light, it has been found possible to detect with dust-free air at atmospheric pressure the non-extinction of the track as seen through a nicol at any orientation. With carbon dioxide the effect is quite conspicuous, and visual determinations of its magnitude have been successfully made by Mr. K. R. Ramanathan working in the present writer's laboratory.

A very interesting question arises whether it is possible to establish the same effect by observations on the polarisation of skylight. As is well known, there is a marked defect in the polarisation of skylight in a direction removed 90° from the sun, which is, however, in the main, due to dust and condensed water-vapour in the atmosphere and the diffuse lighting up of the sky by self-illumination and by reflection from the earth's surface. It occurred to me that the elimination of the effects due to these disturbing factors does not present insuperable difficulties. The reflecting power of landscape (about 0·08 when covered by vegetation) is known, and its effect is therefore calculable. Dust and low-lying mists may be prac-

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tically eliminated by making the observations on a bright, clear day at a high-level station, and the self-illumination of the sky under the same conditions is very small *in respect of wave-lengths near the extreme red end of the spectrum*. The residual effect of self-illumination in these circumstances may be computed with sufficient accuracy by the method used by L. V. King (Phil. Trans. Roy. Soc., A, vol. 212, 1913), the uncertainties due to the neglect of the curvature of the earth and other simplifying assumptions in the calculation being then of little importance.

In order to obtain material for testing these ideas I made observations on the forenoon of December 4 last from the summit of Mount Dodabetta, in the Nilgiris (8750 ft. above sea-level), the sky at the time appearing beautifully clear, free from cirrus clouds, and almost completely black when seen through a deep red filter. The weaker component of polarisation was found to have 13 per cent. of the intensity of the stronger component. Diffuse illumination of the sky is capable of explaining only a part of this, a weaker component of about 8 per cent. intensity being indicated by the calculations. The residual 5 per cent. must therefore be ascribed to molecular anisotropy, and this is in agreement with the laboratory determinations of Rayleigh.

Observations on the molecular scattering of light in *liquids* made by the writer also show an imperfect polarisation attributable to anisotropy. Experiments in the same direction on the atomic scattering of light in crystals are being made, and an attempt is also in progress to discover the existence of an effect indicated by Sir J. J. Thomson's theory (*Phil. Mag.*, October, 1920), namely, the dependence of the results on the frequency of the scattered radiation.

C. V. RAMAN.

210 Bowbazaar Street, Calcutta, December 19.

The Resonance Theory of Hearing.

MAY I reply to Dr. Perrett's letter (NATURE, December 29 last), in which he makes the objection to the resonance hypothesis that it does not explain how we perceive when there are two tones of the same pitch sounding simultaneously?

It seems to me that Dr. Perrett has made two slight errors :—

(1) There must be, he writes, one result, unique and without alternative, when the tracing of the combined wave-form of any two notes of the same frequency is submitted to Fourier analysis.

But surely this cannot be true; for example, if in one case the two tones are 256 vibrations per sec. from an oboe and a flute simultaneously sounded, the relative amplitudes of the overtones found by Fourier analysis would be quite different from those found for the same tone sounded simultaneously on a violin and a cornet. Not only would the amplitudes of the overtones differ in the two cases relatively to the fundamentals, but they would differ also relatively to one another.

(2) Dr. Perrett proceeds: "If the ear acts as a kind of practical Fourier's theorem, it can perceive only one fundamental tone. But we invariably judge of the pitch of a note by its fundamental tone. If, then, we hear at the same time two notes of pitch *n*, the ear must be able to perceive also at the same time two fundamental tones of frequency *n*—that is to say, it must be able to perform an analysis which is not in accordance with Fourier's theorem."

Surely Dr. Perrett has omitted in the above reasoning to take into account the existence of beats, overtones, and phases. If these did not exist, and if the ear could still tell whether one or more than one instrument were contributing to a tone, then the resonance theory would have met with a serious difficulty. But overtones do exist, and they are known to differ for different instruments, also for one instrument in different circumstances, *e.g.* the human voice when sounding various vowels. The resonance theory, in that it explains the perception of overtones, even when their intensity compared with the fundamental is small, also explains how we can tell whether two different instruments are contributing to a tone or one only. But there are other clues; for besides that given by overtones, which in accordance with the resonance hypothesis the ear might make use of, viz. (*a*) if there were beats, due to the two instruments not being exactly in tune, the observer might infer that two were sounding, and not one; (*b*) if the sound-waves from one instrument reached the observer's right ear a little earlier (or later) than they reached his left, whereas those from the other instrument had different time relationships, he might infer that there were two sources of sound, from the observation that the two sources did not occupy the same position relative to his own plane of symmetry; and (*c*) if the sounds from the two instruments did not begin and end together the observer might get information from this also. All these possible methods of observation are compatible with the resonance theory, and therefore it is quite unnecessary to assume that the ear must be able to perform an analysis which is not in accordance with Fourier's theorem. It seems to me, therefore, that Dr. Perrett's objection must fail on all the above grounds.

May I take this opportunity of describing a fresh piece of evidence in favour of the resonance theory? Helmholtz showed, from physical considerations, that the coefficient of "sharpness of tuning" should be inversely proportional to the "persistence" coefficient in the case of resonators responding to tones of different pitch. This relationship does not postulate any special form of resonator, but appears to be a general rule equally as applicable to an electrical oscillating circuit as to a stretched string. If, then, it could be shown that the ear obeys this rule, it would be presumably very strong evidence indeed for the existence of resonators in the cochlea. The following table, calculated from observations by Mayer (published in *Amer. Journ. Sci.*, January, 1894), shows that the necessary evidence exists :—

A	B	C	B × C
Mean tone in vibs. per sec.	Per cent. difference of tone required to stop disonance (tuning factor)	No. of vibrations performed during a subliminal silent interval (persistence factor)	Tuning factor multiplied by persistence factor.
128	12·70	1·78	22·6
256	10·00	2·06	20·6
320	9·45	2·19	20·8
384	9·07	2·18	19·8
512	8·45	2·37	20·0
640	8·15	2·54	20·7
760	7·82	2·68	21·0
1024	7·22	3·01	21·7

Since multiplying tuning factor by persistence factor gives values nearly constant for different resonators (the average error is less than 3 per cent.), as shown in the last column in the above table, the tuning coefficient must be very nearly inversely proportional to the persistence coefficient. That is, the ear behaves quantitatively as it ought to do if it contained resonators.

I find a correction is necessary in my letter to NATURE of January 5. "Tide production" on line 20 should read "tide prediction." H. HARTRIDGE.

King's College, Cambridge.

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